WSDOT FOP for AASHTO T 22[1]

Compressive Strength of Cylindrical Concrete Specimens

1. SCOPE

1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 50 lb/ft^3 [800 kg/m^3].

1.2 The values stated in English units are the standard.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.4 <u>The text of this standard reference notes which provide explanatory material. These notes shall not be considered as requirements of the standard.</u>

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards

T 23 Making and Curing Concrete Test Specimens in the Field
T 24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T 67 Standard Practices for Force Verification of Testing Machines
T 126 Making and Curing Concrete Test Specimens in the Laboratory
T 231 Capping Cylindrical Concrete Specimens

2.2 ASTM STANDARDS

C 683 Test Method for Compressive and Flexural Strength of Concrete Under Field Conditions

C 873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

E 74 Practice for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines.

3. SUMMARY OF TEST METHOD

3.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. SIGNIFICANCE AND USE

4.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

[1]This Test Method is based on AASHTO T 22-03

4.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Methods T23, T24, T126, T231, and ASTM C873.

4.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures and similar uses.

5. APPARATUS

5.1 Testing Machine — The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in Section 7.5. As a minimum, the capacity should be capable of achieving 170% of the design strength.

5.1.1 Verification of calibration of the testing machines in accordance with Method T 67 is required under the following conditions:

5.1.1.1 After an elapsed interval since the previous verification of 18 months maximum, but preferably after an interval of 12 months;

5.1.1.2 On original installation or relocation of the machine;

5.1.1.3 Immediately after making repairs or adjustments which may in any way affect the operation of the (weighing) system or the values displayed, except for zero adjustments that compensate for the weighing of tooling, or specimen, or both; or

5.1.1.4 Whenever there is reason to doubt the accuracy of the results, without regard to the time interval since the last verification.

5.1.2 Design — The design of the machine must include the following features:

5.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of Section 7.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.

Note 1—High-strength concrete cylinders rupture more intensely than normal strength cylinders. As a safety precaution, it is recommended that the testing machines should be equipped with protective fragment guards.

5.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E 74.

Note 2: The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

5.1.3 Accuracy — The accuracy of the testing machine shall be in accordance with the following provisions:

5.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ± 1.0 % of the indicated load.

5.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

5.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, E, and the percentage of error, Ep , for each point from these data as follows:

$$E = A - B$$
$$Ep = 100(A - B)/B$$

where:
A = load, lbf [kN] indicated by the machine being verified, and
B = applied load, lbf [kN] as determined by the calibrating device.

5.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load that can be estimated on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10% of the maximum range capacity.

5.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

5.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.

5.2 The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 3), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 % greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.001 in. [0.025 mm] in any 6 in. [150 mm] of blocks 6 in. [150 mm] in diameter or larger, or by more than 0.001 in. [0.025 mm] in the diameter of any smaller block; and new blocks shall be manufactured within one half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than 0.5 in. [13 mm], concentric circles not more than 0.031 in. [0.8 mm] deep and not more than 0.047 in. [1 mm] wide shall be inscribed to facilitate proper centering.

Note 3: It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than 55 HRC.

5.2.1 Bottom bearing blocks shall conform to the following requirements:

5.2.1.1 The bottom bearing block is specified for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 4). The top and bottom surfaces shall be parallel to each other. Its least horizontal dimension shall be at least 3 % greater than the diameter of the specimen to be tested. Concentric circles as described in Section 5.2 are optional on the bottom block.

Note 4—The block may be fastened to the platen of the testing machine.

5.2.1.2 Final centering must be made with reference to the upper spherical block when the lower bearing block is used to assist in centering the specimen. The center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

5.2.1.3 The bottom bearing block shall be at least 1 in. [25 mm] thick when new, and at least 0.9 in. [22.5 mm] thick after any resurfacing operations, except when the block is in full and intimate contact with the lower platen of the testing machine, the thickness may be reduced to 0.38 in. (10mm).

Note 5: If the testing machine is so designed that the platen itself can be readily maintained in the specified surface condition, a bottom block is not required.

5.2.2 The spherically seated bearing block shall conform to the following requirements:

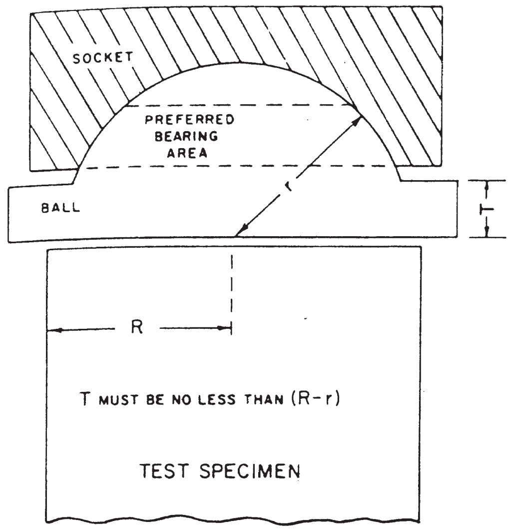
5.2.2.1 The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed the values given below:

Diameter of Test Specimens in. [mm]	**Maximum Diameter of Bearing Face in. [mm]**
2 [50]	4 [105]
3 [75]	5 [130]
4 [100]	6.5 [165
6 [150]	10 [255]
8 [200]	11 [280]

Note 6: Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

5.2.2.2 The center of the sphere shall coincide with the surface of the bearing face within a tolerance of ± 5 % of the radius of the sphere. The diameter of the sphere shall be at least 75 % of the diameter of the specimen to be tested.

5.2.2.3 The ball and the socket must be so designed by the manufacturer that the steel in the contact area does not permanently deform under repeated use, with loads up to 12 000 psi [82.7 MPa] on the test specimen (Note 7).



Schematic Sketch of a Typical Spherical Bearing Block
Figure 1

Note: Provision shall be made for holding the ball in the socket and for holding the entire unit in the testing machine.

Note 7: The preferred contact area is in the form of a ring (described as preferred "bearing" area) as shown on Figure 1.

5.2.2.4 The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with a petroleum-type oil such as conventional motor oil, not with a pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

5.2.2.5 If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere (see Figure 1).

5.2.2.6 The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted at least 4 degrees in any direction.

5.3 Load Indication:

5.3.1 If the load of a compression machine used in concrete testing is registered on a dial, the dial shall be provided with a graduated scale that is readable to at least the nearest 0.1 % of the full scale load (Note 8). The dial shall be readable within 1 % of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment which is easily accessible from the outside of the dial case, while observing the zero mark and dial pointer, and with a *suitable device that at all times until reset will indicate to within one percent accuracy the maximum load applied to the specimen*.

Note 8: As close as can reasonably be read is considered to be 0.02 in. [0.5 mm] along the arc described by the end of the pointer. Also, one half of a scale interval is close as can reasonably be read when the spacing on the load indicating mechanism is between 0.04 in. [1 mm] and 0.06 in. [2 mm]. When the spacing is between 0.06 and 0.12 in. [2 and 3 mm], one third of a scale interval can be read with reasonable certainty. When the spacing is 0.12 in. [3 mm] or more, one fourth of a scale interval can be read with reasonable certainty.

5.3.2 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 % of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 % for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1.0 % system accuracy the maximum load applied to the specimen.

6. SPECIMENS

6.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %. (Note 9).

Note 9: This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding or when a core drill deflects or shifts during drilling.

6.2 Neither end of compressive test specimens when tested shall depart from perpendicularity to the axis by more than 0.5 degrees (approximately equivalent to 0.12 in. in 12 in. (3 mm in 300 mm). The ends of compression test specimens that are not plane within 0.002 in. [0.050 mm] shall be capped, sawed or ground in accordance with T 231 or if the ends meet the requirements of A6, then neopreme caps with steel controllers may be used instead of capping. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.01 in. [0.25 mm] by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

6.3 The number of individual cylinders measured for determination of average diameter may be reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.02 in. [0.5 mm]. When the average diameters do not fall within the range 0.02 in. (0.5 mm) or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

6.4 The length shall be measured to the nearest 0.05 D when the length to diameter ratio is less than 1.8, or more than 2.2, or when the volume of the cylinder is determined from measured dimensions.

7. PROCEDURE

7.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

7.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

7.3 All test specimens for a given test age shall be broken within the permissible time tolerances prescribed as follows:

Test Age	**Permissible Tolerance**
12 h	± 0.25 h or 2.1 %
24 h	± 0.5 h or 2.1 %
3 days	2 h or 2.8 %
7 days	6 h or 3.6 %
28 days	20 h or 3.0 %
90 days	2 days 2.2 %

7.4 Placing the Specimen Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

7.4.1. *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 10). ~~As~~ Prior to the spherically-seated block ~~is~~ being brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

Note 10—The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

7.5 Rate of Loading-Apply the load continuously and without shock.

7.5.1 For testing machines of the screw type, the moving head shall travel at a rate of approximately 0.05 in. [13 mm]/min when the machine is running idle. For hydraulically operated machines, the load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a loading rate on the specimen within the range of 20 to 50 psi/s [0.15 to 0.35 MPa/s]. The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase of the testing cycle.

7.5.2 During the application of the first half of the anticipated Loading phase a higher rate of loading shall be permitted.

7.5.3 Make no adjustment in the rate of movement of the platen at any time while a specimen is yielding rapidly immediately before failure.

7.6 Apply the load until the specimen fails, (see note WSDOT 1)and record the maximum load carried by the specimen during the test. Note the type of failure and the appearance of the concrete (see Figure 2).

Note WSDOT 1: The test loading should be stopped when 80% of the loading capacity of the testing machine has been reached. Record the maximum load achieved and note that the sample was not taken to failure as it exceeded the safe working limits of the testing machine.

8. CALCULATION

8.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 6 and express the result to the nearest 10 psi [0.1 MPa].

8.2 If the specimen length to diameter ratio is less than 1.8, correct the result obtained in Section 8.1 by multiplying by the appropriate correction factor shown in the following table:

L/D:	1.75	1.50	1.25	1.00	
Factor:	0.98	0.96	0.93	0.87	(Note 11)

Note 11: These correction factors apply to lightweight concrete weighing between 100 and 120 lb/ft 3 [1600 and 1920 kg/m 3] and to normal weight concrete. They are applicable to concrete dry or soaked at the time of loading. Values not given in the table shall be determined by interpolation. The correction factors are applicable for nominal concrete strengths from 2000 to 6000 psi [15 to 45 MPa].

9. Report

9.1 Report the following information:

9.1.1 Identification number;

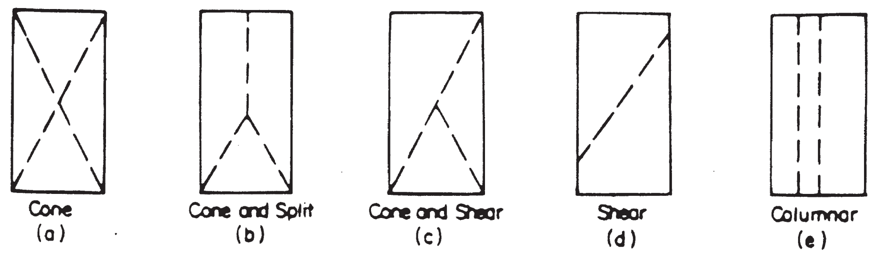
9.1.2 Diameter (and length, if outside the range of 1.8D to 2.2D), in inches or millimeters;

9.1.3 Cross-sectional area, in square inches or centimeters;

9.1.4 Maximum load, in pounds-force or newtons;

9.1.5 Compressive strength calculated to the nearest 10 psi or 0.1MPa;

9.1.6 Type of fracture, if other than the usual cone (see Figure 2);



Sketches of Types of Fracture
Figure 2

9.1.7 Defects in either specimen or caps; and

9.1.8 Age of specimen.

10. PRECISION AND BIAS

10.1 Precision —The single operator precision of tests of individual 150- by 300-mm (6- by 12-in.) cylinders made from a well-mixed sample of concrete is given in the table below for cylinders made in a laboratory environment and under normal field conditions. (See Section 10.1.1.)

Table 3—Acceptable Range of Coefficient of Variation

	Coefficient of ariation[a]	Acceptable Range of [a]	
		Two Results	Three Results
Single operator			
Laboratory conditions	2.37 percent	6.6 percent	7.8 percent
Field conditions	2.87 percent	8.0 percent	9.5 percent

a These numbers represent respectively the (1s) and (d2s) limits as described in Practice C 670.

10.1.1 The values given are applicable to 150- by 300-mm (6- by 12-in.) cylinders with compressive strength between 15 to 55 MPa (2000 and 8000 psi).

10.1.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

APPENDIX A

Compressive Strength of Cylindrical Concrete Specimens Using Neoprene Caps

A1. SCOPE

A1.1 This method covers the procedure for compressive strength testing of 6 in. (152 mm) diameter by 12 in. (305 mm), or 4 in. diameter by 8 in. concrete cylinders using neoprene caps with steel extrusion controllers. Provisions are made for alternate reusable cap systems which utilize other materials for pads and extrusion controllers than neoprene and steel.

A2. REFERENCED DOCUMENTS

A2.1 AASHTO Standard:

T 231 Capping Cylindrical Concrete Specimens

A2.2 ASTM Standard:

D 2000 Rubber Products in Automotive Applications

A3. SIGNIFICANCE AND USE

A3.1 Use of neoprene caps should be considered as a suitable alternate for compressive strength testing. Alternate reusable cap systems must be verified in accordance with paragraphs A11 through A12.

A4. APPARATUS

A4.1 Two steel extrusion controllers shall be used (See Table 1). An acceptable configuration for extrusion controllers used for 6 inch diameter cylinders is shown in Figure 3. Other modes of manufacture may be used such as steel casting or machining in one piece from round stock provided the inside diameter, minimum wall thickness, and minimum bearing surface thickness comply with the dimensions shown in Figure 3 for extension controller used for 6 inch diameter cylinders. For extension controller used for 4 inch diameter cylinders, the inside diameter of the extension controller shall not be less than 102 % or greater than 107 % of the diameter of the cylinder. All bearing surfaces of the controller, both inside and outside, shall be machine planed to within 0.002 in. (0.05 mm). During use, the outside bearing surface shall be maintained free of gouges, or dents larger than 0.010 in. (0.25 mm) in depth or 0.05 in.^{2} (32 mm^2) in surface area. Protrusions of any kind will not be allowed.

Table 1
Tolerances

Controller I.D.	0″ (0 mm)	$+^1/_{32}$″ (+0.3 mm)
Controller wall	$-^1/_{16}$″ (-11.6 mm)	+0″ (+0 mm)
Any tolerance not specified	$-^1/_{64}$″ (-0.4 mm)	$+^1/_{64}$″ (+0.4 mm)

A4.2 For 6 inch reusable neoprene caps, the pads shall be ~~Caps~~ made from neoprene meeting the requirements of ASTM D 2000, line call-out M2BC514A14B14. The dimensions of the caps shall be 6 1/8 in. (155.6 mm) in diameter and ½ in. (12.7 mm) thick.

A4.2.1 For 4 inch reusable neoprene cap, the pad shall be ½ in. thick and the diameter shall not be more that 1/16 in. smaller than the inside diameter of the extension controller.

A4.3 A compression testing machine meeting the requirements of the main test method.

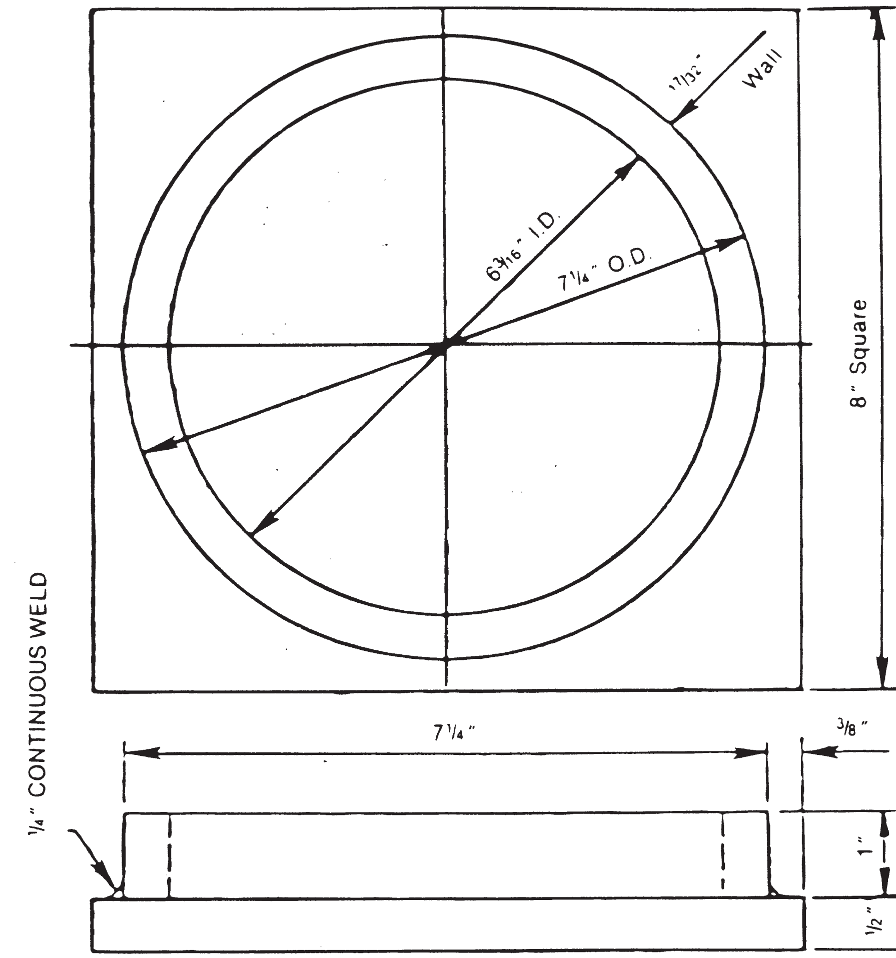


FIGURE A1

NOTE—Metric equivalents for Figure A1 are listed below.

Inches	1/2	1	6	6 1/8	6 3/16	7 1/4	8	12
mm	12.7	25.4	152.4	155.6	157.2	184.2	203.2	304.8

Figure 3

A5. PRECAUTIONS

A5.1 Concrete cylinders tested with neoprene caps rupture more intensely than comparable cylinders tested with sulphur-mortar caps. As a safety precaution, the cylinder testing machine should be equipped with a protective cage.

A5.2 The loading rate for some testing machines may have to be adjusted when using neoprene caps.

A6. TEST SPECIMENS

The test specimens shall be that as detailed in the main test method, modified as follows:

A6.1 Each end of the concrete cylinder shall be plane within 1/8 in. (3.2 mm) across any diameter; i.e., there shall be no depressions in the concrete surfaces which are deeper than 1/8 in. (3.2 mm). Cylinders which do not meet this tolerance shall not be tested unless the surface irregularity is first corrected.

A6.2 Neither end of compressive test specimens when tested shall depart from perpendicularity to the axis by more than 2.0 degrees (approximately equal to a difference in height of $^3/_{16}$ in. (4.8 mm) for two – 6 in (152 mm) diameter cylinders. cylinders not meeting this tolerance shall not be tested unless this irregularity is first corrected.

A7. PROCEDURE

The procedure followed shall be that as detailed in the main test method, modified as noted below:

A7.1 Place an extrusion controller, containing a neoprene cap, on the top and bottom surfaces of the concrete cylinder. With the neoprene caps in contact with the concrete cylinder, carefully align the axis of the specimen with the center of thrust of the spherically seated block. Bring the bearing blocks of the machine in contact with both of the extrusion controllers.

A7.2 No loose particles shall be trapped between the concrete cylinder and the neoprene caps or between the bearing surfaces of the extrusion controllers and the bearing blocks of the test machine.

A7.3 The same surface of the neoprene cap shall bear on the concrete cylinder for all tests performed with that cap. Each neoprene cap shall not be used to test more than 100 cylinders. The life of alternate pads must be verified by the agency (or purchaser) in accordance with paragraph A12.4.

A8. CALCULATION

The compressive strength shall be calculated as described in Section 8.1 of the main test method.

A9. REPORT

The report shall contain all the items noted in Section 9 of the main test method.

A10. PRECISION AND ACCURACY

A10.1 Testing variation associated with neoprene caps is o higher and possibly lower than that associated with sulfur-mortar caps. Based on a study, coefficients of variation associated with neoprene caps were within the range (0.0 to 4.0 percent) and considered to represent excellent control.

A10.2 Neoprene caps should be considered as an acceptable substitute for sulfur-mortar caps without correction for apparent strength differences.

A11. ALTERNATE REUSABLE CAP SYSTEMS

A11.1 Commercial systems are available which utilize reusable caps manufactured from materials other than neoprene and extrusion controllers of metals other than steel. An alternate reusable cap system may be used provided the following criteria, manufacturer, and agency (or purchaser) verifications are satisfied.

A12. CRITERIA FOR ACCEPTANCE OF ALTERNATE REUSABLE CAP SYSTEMS

A12.1 The system must utilize reusable caps retained within extrusion controllers. Tolerances on all bearing surfaces of the extrusion controllers shall meet the requirements of Section A4.1.

A12.2 Reusable caps shall provide a minimum of 0.5 in (12.7 mm.) compressible thickness over the entire bearing area. The manufacturer shall supply reusable caps which are uniform in dimensions and physical properties.

A12.3 Manufacturer Verification of Alternate Reusable Cap Systems:

A12.3.1 The manufacturer shall provide results of a two-factor factorial experiment with capping method as the main factor and concrete batch as the secondary factor. For the estimation of variances for error, interaction among factors, or for factors, the cap system factor shall be considered a fixed variable and the batch factor shall be considered a random variable. The experiment shall be repeated at three levels of concrete strength at 28 days, representing a range of average strength of 2000 to 6000 psi (13.8 to 41.4 MPa) 2000 (13.8), 4000 (27.6), 6000 (41.4) psi (MPa) recommended. The F test level of significance for testing significance of difference among variances shall be 0.05.

A12.3.2 In conducting the experiment, a minimum of eight batches of four cylinders per batch shall be prepared at each level of strength, yielding two replicates for each capping method X batch combination. Within each batch, equal numbers of cylinders shall be randomly chosen for testing by the reusable cap system and by T 231. The sequence of testing for capping method X batch X level of strength cells shall be randomized. If laboratory facilities do not permit fabrication of all cylinders within one day, cylinders for one complete strength level shall be fabricated on each of three successive days; sequence of testing for capping method X batch will be randomized. One set of new pads shall be used for all tests within each strength level. At the option of the manufacturer, one set of new pads may be used for all tests at all strength levels; but sequence of testing for capping method X batch X strength level cells shall be randomized.

A12.3.3 Specific statistical equivalencies to be demonstrated by the manufacturer shall be as follows:

A12.3.3.1 The analysis of variance of each strength level shall show no significant effect of capping method.

A12.3.3.2 The estimate of average difference in strength between capping methods utilizing the cell averages for each capping method X batch X level of strength cell shall not be significantly different from zero. The paired t test at a level of significance of 0.10 shall be used.

Note 12: One reference describing factorial experiments is “Fundamental Concepts in the Design of Experiments” by Charles R. Hicks, Holt, Rinehart, and Winston.

A12.4 Agency (or Purchaser) Verification of Alternate Reusable Cap Systems:

A12.4.1 Prior to implementation of a reusable cap system, the agency (or purchaser) shall conduct an in-house evaluation comparing compressive strength and variability for sets of field cylinders manufactured from the same samples of concrete; the reusable cp system shall be compared to T 231. The paired t test shall be used at a level of significance of 0.10.

A12.4.2 A minimum of 30 sets of cylinders shall be compared for compressive strength for one evaluation with one set of reusable pads; however, the number of sets may be increased (to determine usable life) if the reusable caps have not developed visible damage such as splitting, gouging, or a permanent compression set I the bearing area in 30 repetitions. The evaluation shall be repeated at least once with a new set of reusable caps. Job control cylinders of two or more per set cast from the same sample bay be used. If cylinders are cast from successive batches in a laboratory, selection of cylinders shall be randomized among batch X capping method.

A12.4.3 The agency (or purchaser) shall reject a reusable cap system if the in-house evalation shows significant difference in compressive strength or variability as compared to T 231.

A12.4.4 The agency (or purchaser) shall reserve the right to reject a reusable cap system if the number o possible repetitions or life of a set of caps is not acceptable to the agency (or purchaser).

Performance Exam Checklist

Compressive Strength of Cylindrical Concrete Specimens FOP for AASHTO T 22

Participant Name ______________________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	☐	☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	☐	☐
3. Is the diameter of the cylinder record to the nearest 0.01 inch by averaging two diameters taken at about mid-height?	☐	☐
4. Are lower and upper bearing surface wiped clean?	☐	☐
5. Is the axis of the cylinder aligned with center of the spherical block?	☐	☐
6. Is the spherical block rotated prior to it contact~~s~~ with the cylinder?	☐	☐
7. Is the load applied continuously and without shock?	☐	☐
8. Is the load applied at the specified rate and maintain for the latter half of the anticipated load.	☐	☐
9. Is no rate adjustment made while the cylinder is yielding?	☐	☐
10. Is the maximum load recorded?	☐	☐
11. Are cylinders tested to failure, or to 80% capacity of machine, and the type of fracture recorded?	☐	☐
12. Breaking Cylinders (Tolerance)		
1 day ($^1/_2$ hour)	☐	☐
3 day (2 hours)	☐	☐
7 day (6 hours)	☐	☐
28 day (20 hours)	☐	☐
13. All calculations performed correctly?	☐	☐
Pad Cap-concrete Cylinders AASHTO-22 Appendix A		
1. Ends of cylinders checked for perpendicularity to axis?	☐	☐
2. Ends of cylinders checked for depressions greater than 0.2 inch?	☐	☐
3. Pads examined for splits or cracks?	☐	☐
4. Cylinders centered in retaining rings?	☐	☐
5. Is cylinders checked for alignment with a small load applied?	☐	☐

First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

Signature of Examiner ______________________________

Comments: